Chemical Category: METAL

Chemical Name (Common Synonyms): NICKEL **ASRN:** 7440-02-0

Chemical Characteristics

Solubility in Water: Insoluble [1] **Half-Life:** Not applicable, stable [1]

Log K_{ow}: – **Log K_{oc}:** –

Human Health

Oral RfD: 2×10^{-2} mg/kg/day [2] **Confidence:** Medium uncertainty factor = 300

Critical Effect: Decreased body and organ weights

Oral Slope Factor: Not available [2] **Carcinogenic Classification:** A [2]

Wildlife

Partitioning Factors: Partitioning factors for nickel in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for nickel in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Nickel in the aquatic environment can partition to dissolved and particulate organic carbon. Also, the bioavailability of nickel can be influenced to some extent by the concentrations of calcium and magnesium in water. The bioavailability of nickel in sediments is controlled by the concentration of acid-volatile sulfides (AVS) [8].

Food Chain Multipliers: Little evidence exists to support the general occurrence of biomagnification of nickel in the aquatic environment [9 and 10].

Toxicity/Bioaccumulation Assessment Profile

Bioaccumulation of nickel is most pronounced in sediments when the ratio of simultaneously extracted metals to acid-volatile sulfide (SEM/AVS) is greater than 1. Although nickel concentrations in animals from sediments with SEM/AVS ratios >1 were approximately 2- to 10-fold greater than nickel concentrations in benthic organisms from sediments with SEM/AVS ratio <1, nickel uptake (tissue concentration) was proportional to the concentration in sediment. Ankley et al. [3] have shown that bioaccumulation of nickel from the sediment by *Lumbriculus variegatus* was not predictable based on total sediment metal concentration, but was related to the sediment SEM/AVS ratio.

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Lumbriculus		0.58 µmol/L	0.10 µmol/g					[3]	F
variegatus,		16.44 µmol/L	5.00 µmol/g						
Oligochaete worm		38.24 µmol/L	3.32 µmol/g						
		31.40 µmol/L	0.87 µmol/g						
		4.53 µmol/L	0.07 µmol/g						
		32.77 µmol/L	0.33 µmol/g						
		8.58 µmol/L	1.88 µmol/g						
		14.43 µmol/L	0.97 µmol/g						
		3.72 µmol/L	3.59 µmol/g						
		17.96 µmol/L	2.77 µmol/g						
		0.52 µmol/L	0.10 µmol/g						
		2.75 µmol/L	0.29 µmol/g						
		0.50 µmol/L	1.41 µmol/g						
		3.51 µmol/L	1.91 µmol/g						
		16.67 µmol/L	7.79 µmol/g						
		17.20 µmol/L	0.95 µmol/g						
Tubificidae	51 µg/g		7.20 mg/g					[6]	L
	50 µg/g		3.19 mg/g						
	93 µg/g		6.96 mg/g						
	76 µg/g		12.04 mg/g						
	75 µg/g		9.45 mg/g						

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Neanthes arenaceodentata, Polychaete worm		<0.28 µmol/L	<0.002 µmol/g	3% mortality				[4]	F
		0.42 µmol/L	0.01 µmol/g	13% mortality					
		2.62 µmol/L	0.01 µmol/g	0% mortality					
		0.16 µmol/L	<0.002 µmol/g	3% mortality					
		<0.74 µmol/L	<0.001 µmol/g	7% mortality					
		3.72 µmol/L	0.01 µmol/g	13% mortality					
		0.37 µmol/L	0.02 µmol/g	0% mortality					
		0.80 µmol/L	<0.006 µmol/g	0% mortality					
		54.30 µmol/L	0.12 µmol/g	20% mortality					
		1.28 µmol/L	<0.002 µmol/g	7% mortality					
		64.8 µmol/L	0.05 µmol/g	10% mortality					
		67.4 µmol/L	0.06 µmol/g	0% mortality					
		36.4 µmol/L	0.12 µmol/g	3% mortality					
		0.86 µmol/L	0.02 µmol/g	0% mortality					
		73.1 µmol/L	0.10 µmol/g	0% mortality				[5]	F
		52.4 µmol/L	0.21 µmol/g	0% mortality					
		449 µmol/L	1.69 µmol/g	3% mortality					
Cerastoderma edule, Clam			56.6 mg/kg (whole body)[4]	Mortality, ED50				[12]	L; estimated body residue by regression from other data values, number of replicates is 2 to 5

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			128 mg/kg (adductor muscle)[4]	Physiological, NOED				[12]	L; no significant effect on respiration rate at 100 µg/L (highest test concentration at which body residues were measured), number of replicates is 2 to 5
			140 mg/kg (foot)[4]	Physiological, NOED				[12]	
			209 mg/kg (gill)[4]	Physiological, NOED				[12]	
			274 mg/kg (mantle)[4]	Physiological, NOED				[12]	
			138 mg/kg (visceral tissue)[4]	Physiological, NOED				[12]	
			167 mg/kg (whole body)[4]	Physiological,NOED				[12]	
Mytilus galloprovincialis, Mussel			1.1-1.4 mg/kg				0.22	[11]	F
Lamellidans marginalis, Freshwater mussel	110 mg/L		Day 4: 1456.1 µg/g (ctenidium) 432.7 µg/g (mantle) 468.3 µg/g (hepatopancreas) 328.4 µg/g (foot) 373.9 µg/g (adductor muscle)					[5]	L

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Lamellidans marginalis, Freshwater mussel	22 mg/L		Day 15: 569.8 µg/g (ctenidium) 277.1 µg/g (mantle) 327.1 µg/g (hepatopancreas) 218.6 µg/g (foot) 186.7 µg/g (adductor muscle)					[5]	L
Daphnia magna, Cladoceran			223 mg/kg (whole body)[4]	Mortality, ED50				[6]	L; lethal body burden after 21-day exposure
Fishes									
Cyprinus carpio, Carp		40 mg/L	Day 4: 202.8 mg/L (gill) 226.3 mg/L (kidney) 82.2 mg/L (liver) 97.1 mg/L (brain) 118.1 mg/L (white muscle)					[5]	L
		8 mg/L	Day 15: 103.0 mg/L (gill) 80.3 mg/L (kidney) 97.1 mg/L (liver) 40.6 mg/L (brain) 58.0 mg/L (white) muscle)						

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Pimephales	31 µg/g		8.69 mg/g					[7]	F
promelas,	51 µg/g		8.19 mg/g						
Fathead minnow	50 µg/g		5.66 mg/g						
	57 µg/g		4.02 mg/g						
	93 µg/g		10.72 mg/g						
	73 µg/g		10.10 mg/g						
	76 µg/g		11.51 mg/g						
	60 µg/g		13.32 mg/g						
	75 µg/g		11.75 mg/g						
	53 µg/g		10.90 mg/g						

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (CHLOROPHENOXY)

Chemical Name (Common Synonyms): OXYFLUORFEN **CASRN:** 42874-03-3

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2]

Log K_{ow}: No data [3]

Log K_{oc}: —

Human Health

Oral RfD: 3×10^{-3} mg/kg/day [4]

Confidence: High, uncertainty factor = 100

Critical Effect: Increased absolute liver weight and nonneoplastic lesions in mice

Oral Slope Factor: 1.3×10^{-1} per (mg/kg)/day [5]

Carcinogenic Classification: C [5]

Wildlife

Partitioning Factors: Partitioning factors for in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for oxyfluorfen in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for oxyfluorfen in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for oxyfluorfen in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

A light activated herbicide, oxyfluorfen at 10^{-2} mM increased cell membrane permeability in *Lemna minor* [6]. The screening tissue value for fish for oxyfluorfen presented by the Chesapeake Bay Program is 800 ng/g [7].

Summary of Biological Effects Tissue Concentrations for Oxyfluorfen

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates			**[NO DATA]**						
Fishes			**[NO DATA]**						
Wildlife			**[NO DATA]**						

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

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Chemical Category: BIPHENYLS

Chemical Name (Common Synonyms): 2,4,4′-TRICHLOROBIPHENYL **CASRN:** 7012-37-5

Chemical Characteristics

Solubility in Water: No data [1], 160 µg/L [2]

Half-Life: No data [3,4]

Log K_{ow}: 5.60 [2]

Log K_{oc}: 5.51 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: No partitioning factors were identified for wildlife.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. Log biomagnification factors of 1.07 and 1.97 were determined for total PCBs from alewife to herring gull eggs and from alewife to whole body herring gull, respectively [11]. No specific food chain multipliers were identified for PCB 28.

Aquatic Organisms

Partitioning Factors: Biota-sediment accumulation factors (BSAFs) range from 1.5 to 18.2 for aquatic invertebrate species. The highest BSAF was provided for marine crustaceans.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 28 or other trichlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [23]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [24]. Examples of these more toxic, coplanar congeners are

3,3′,4,4′-trachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [25]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [25,26]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high Kow values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [27]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [27]. Once taken up by an organism, partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [28]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [29, 30]. In some species, tissue concentrations of in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred are eliminated from the female during spawning [31,32]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [31]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [16].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [33]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [33]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [33]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [34], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 [35].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [36] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [37] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for PCB 28

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Microcystis aeruginosa, *Daphnia longispina*, Plankton	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		0.23 ± 0.22 ng/g (n=14)				3.3	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 0.65%
Plankton, Species not reported	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.350[4] (mean) SD = 0.2353 (n = 5) µg/kg					[39]	F; collected in western Lake Erie (offshore Middle Sister Island); sediment TOC = 7.4% (SD = 1.78), lipid = 1.2% (mean) SD = 0.24
Dreissena polymorpha, Zebra mussel	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.431[4] (mean) SD = 0.4642 (n = 20) µg/kg						lipid = 1.3% (mean) SD = 0.34
Dreissena polymorpha, Zebra mussel	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		0.52 ± 0.36 ng/g (n = 5)				2.8	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 1.74%
Corbicula fluminea, Bivalve	Station B6: 0.4[4] ng/g dw Station C10: 0.03[4] ng/g dw	1.1[4] ng/L <DL[4]	0.33[4] µg/g[5] of lipid (whole animal) 0.3 µg/g[5] of lipid					[40]	F; samples collected from the Rio de la Plata. Sediment depth samples was 0-5 cm. Water sample was filtered.

Summary of Biological Effects Tissue Concentrations for PCB 28

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Crustaceans *Gammarus tigrinus, Assellus aquaticus, Orchestra carimana*	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		2.93 ± 1.41 ng/g (n = 7)				18.2	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 0.86%
Gammarus fasciatus, Amphipod	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.666[4] (mean) SD = 0.2768 (n = 4) µg/kg						lipid = 2.1% (mean) SD = 1.04
Orconectes propinquus, Crayfish	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.392[4] (mean) SD = 0.2407 (n = 5) µg/kg						lipid = 1.7% (mean) SD = 0.11
Hydropsyche alterans, Caddisfly larva	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.369[4] (n = 1) µg/kg						lipid = 1.7% (mean)
Fishes									
Prochilodus platensis, Fish	Station F17: 0.08[4] ng/g dw	<DL[4]	0.9[4]µg/g[5] of lipid					[40]	F; samples collected from the Rio de la Plata.
Oligosarcus jenynsi, Fish	Station A1: 6[4] ng/g dw	0.7[4] ng/L	0.3[4] µg/g[5] of lipid					[40]	F; samples collected from the Rio Santiago.

Summary of Biological Effects Tissue Concentrations for PCB 28

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Anguilla anguilla, Eel	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		3.98 ± 3.42 ng/g (n = 6)				1.5	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 14.9%

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Reported concentrations reflect both congeners 28 and 31.
[5] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): 3,3′,4,4′-TETRACHLOROBIPHENYL **CASRN:** 32598-13-3

Chemical Characteristics

Solubility in Water: 0.18 mg/L [1]

Half-Life: No data [2,3]

Log K_{ow}: No data [4], 6.1 [5]

Log K_{oc}: —

Human Health

Oral RfD: No data [6]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [6]

Carcinogenic Classification: No data [6]

Wildlife

Partitioning Factors: Bioaccumulation factors (BAFs) were determined for mink. The mink had less PCB-77 in their tissues than was measured in their diet. BAF values ranged from 0.1 to 0.2.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [7]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [8,9,10]. The results from Biddinger and Gloss [8] and USACE [10] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [11] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. Log biomagnification factors (BMFs) for tetrachlorobiphenyls from alewife to herring gulls ranged from 1.52 to 1.83, but were not measured specifically for PCB 77 [12]. A study of arctic marine food chains measured log biomagnification factors for tetrachlorobiphenyls that ranged from 0.08 to 0.40 for fish to seal, <-0.40 for seal to bear, and <-0.30 for fish to bear [13]. Log BMFs calculated for mink fed PCB 77-contaminated feed ranged from -1.00 to -0.70 [40].

Aquatic Organisms

Partitioning Factors: Log bioconcentration factors (BCFs) for blue mussels deployed in New Bedford Harbor, MA, were approximately 6.40 and 6.60 during two years of the study, as reported in the attached summary table [42].

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [14], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [15] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 77 or other tetrachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [16]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [16]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [17]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [17]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [18]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [17] , whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [19]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [20,21] and total organic carbon content [20,21,22,23]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [17]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [19]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [17]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [19].

The persistence of PCBs in the environment is a result of their general resistance to degradation [18]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [24]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [18]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [23].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [25]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [26]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [27]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [27,28]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [29]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [29]. Once taken up by an organism, PCBs partition primarily into lipid compartments [17]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [17]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [30]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [31,32]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [33,34]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [33]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [18].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [35]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [35]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [35]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [36], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [37].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [18]. Field and Dexter [18] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al [38] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [39] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [18].

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Mytilus edulis, Blue mussel		1993: Particulate 1.7 µg/L ±0.5 n = 9 Dissolved 1.0 µg/L ±0.1 n = 9			~6.60			[42]	F; New Bedford Harbor, MA; deployment study; tissue concentrations were only presented for 1994 samples; BCF and tissue concentrations are approximations (~) as data were taken from figure
Mytilus edulis, Blue mussel		1994: Particulate 2.3 µg/L ±0.9 n = 3 Dissolved 0.9 µg/L ±0.1 n = 3	-360 ng/g dw (whole body)		~6.40			[42]	Presented for 1994 samples; BCF and tissue concentrations are approximations (~) as data were taken from figure

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Daphnia magna, Freshwater cladoceran		exposure water 0.1 µg/L	~6.5 ng/mg dw (n = 3)	No significant effect on survival or reproduction; increased biomass				[40]	L; 21-day static renewal tests; tissue concentrations are approximations (~), as data were taken from figures
		1.0 µg/L	~55 ng/mg dw (n = 3)	No significant effect on survival or reproduction; decreased biomass					
Mysis relicta, Epibenthic freshwater shrimp	118.47 µg/kg dw (TOC = 22.8%)		Screened mysids: 0.72 µg/kg					[41]	L; mysids exposed to field contaminated sediments from Lake Champlain, NY; 24-day exposure; screened mysids were screened from direct contact with sediments (% lipid = 5.94 ± 0.27) whole body;
			Unscreened mysids: 8.74 µg/kg						unscreened mysids were allowed to burrow into sediment.(% lipid = 5.80 ± 0.18) whole body

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**BCF**	**BAF**	**BSAF**	**Reference**	**Comments[3]**
Strongylocentrotus droebachiensis, Sea urchin	0.050 ng/g		0.087 ng/g					[43]	F; sediment and biota collected near or in Hamlet in Cambridge Bay, NW Territories, Canada.
Fishes									
Myoxocephalus quadricornis, Fourhorn sculpin	0.050 ng/g dw		0.056 ng/g (liver) 0.11ng/g (whole body)					[43]	F; sediment and biota collected near or in Hamlet in Cambridge Bay, NW Territories, Canada.
Salmonids							0.29	[47]	F
Wildlife									
Falco peregrinus, Peregrine falcon			1.5 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[46]	F; Kola Peninsula, Russia
White leghorn chicken (embryo)			2.6 µg/kg (egg) 8.6 µg/kg (egg)	LD50 LD50				[44]	L; PCBs were injected into the air cell of eggs

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 11 pg/g[4]		50 pg/g[4] (liver)	NOAEL		No BMF reported		[45]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	300 pg/g[4]		45 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = −0.70			
	600 pg/g[4]		50 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = −1.00			
	1,100 pg/g[4]		90 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = −1.00			

[1] Concentration units expressed in wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): 3,4,4′,5-TETRACHLOROBIPHENYL **CASRN:** 70362-50-4

Chemical Characteristics

Solubility in Water: No data [1,2]

Half-Life: No data [2,3]

Log K_{ow}: No data [2,4]

Log K_{oc}: —

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: Bioaccumulation factors were determined for mink. At PCB 81 concentration ≥ 66 pg/g, the mink had less PCB 81 in their tissues (liver) than was measured in their diet. At low PCB 81 concentrations (e.g., 27 pg/g), there was an increase in the tissue burden. Log BAF values ranged from −0.10 to 0.23.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. Log biomagnification factors for tetrachlorobiphenyls from alewife to herring gulls ranged from 1.52 to 1.83, but were not measured specifically for PCB 81 [11]. A study of arctic marine food chains measured log biomagnification factors for tetrachlorobiphenyls that ranged from 0.08 to 0.40 for fish to seal, <−0.4 for seal to bear, and <−0.3 for fish to bear [12]. No specific food chain multipliers were identified for PCB 81.

Aquatic Organisms

Partitioning Factors: No partitioning factors were identified for aquatic organisms.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 81.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and

2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30, 31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 81

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Tubifex sp, Oligochaetes	0.0006 mg/kg (n = 1)		0.0003 mg/kg (one composite)					[39]	F; lower Detroit River
Fishes									
Cyprinus carpio, Carp	0.0006 mg/kg (n = 1)		0.021±0.012 mg/kg (n = 9)					[39]	F; lower Detroit River
Salmonids							0.67	[42]	F
Wildlife									
Bucephala clangula, Goldeneye	0.0006 mg/kg (n = 1)		0.017±0.0002 mg/kg (n = 3)					[39]	F; lower Detroit River
Aythya affinis, Lesser scaup	0.0006 mg/kg (n = 1)		0.31±0.017 mg/kg (n = 7)					[39]	F; lower Detroit River
Aythya marila, Greater scaup	0.0006 mg/kg (n = 1)		0.046±0.016 mg/kg (n = 3)					[39]	F; lower Detroit River
Falco peregrinus, Peregrine falcon			0.14 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[40]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for PCB 81

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 2 pg/g[4]		50 pg/g[4] (liver)	NOAEL		No BMF reported		[41]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	27 pg/g[4]		45 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 0.23			
	66 pg/g[4]		50 pg/g[4] (liver)						
	150 pg/g[4]		100 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = −0.10			
				Significant decrease in number of live kits whelped per female		Log BMF = 0.00			

[1] Concentration units in wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 32598-14-4
2,3,3′,4,4′-PENTACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1], 0.0008 - 0.17 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: 5.6 - 6.5 [2], No data [4]

Log K_{oc}: 5.51 - 6.39 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: One study reported biomagnification factors (BMFs) for mink exposed to PCB-contaminated food. The lipid-normalized BMFs ranged from 3.8 to 6.8 indicating an accumulation of this PCB congener in the liver.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factor for PCB 105 from alewife to herring gulls in Lake Ontario was 2.01 [11]. A study of arctic marine food chains measured log biomagnification factors for pentachlorobiphenyls that ranged from 0.71 to 1.05 for fish to seal, 0.28 to 0.49 for seal to bear, and 1.14 for fish to bear [12].

Aquatic Organisms

Partitioning Factors: Two studies were found that reported laboratory-measured data to calculate non-normalized log bioaccumulation factors (BAFs) and biota-sediment accumulation factors (BSAFs). In the first study the log BAFs determined for marine clams ranged from 0.86 to 1.35 [41]. The BSAFs ranged from 1.63 to 3.85, with the highest BSAF value associated with the lowest BAF. In the second study, only BSAF for marine clams were reported. These values ranged from 0.22 to 0.68 [42]. A BSAF of 4.49 was determined for salmonids [46].

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 105 or other pentachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34].

Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 105

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Plankton, Species not given	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	Surface water: 0.003 (mean) SD = 0.0020 (n = 3) ng/L	0.666 (mean) SD = 0.1881 (n = 5) fg/kg					[39]	F; collected in western Lake Erie (offshore Middle Sister Island). Sediment TOC = 7.4% (SD-1.78); lipid = 1.2% (mean) SD-0.24
Plankton (a mixture of primarily phytoplankton and some zooplankton)	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	0.8 ± 0.2 ng/g (n = 3)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 0.5%
Mainly *Tubifex tubifex* and *Limnodrilus hoffmeisteri,* Oligochaete	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	2.6 ± 1.4 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 1%
Dreissena polymorpha, Zebra mussel	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	1.627 (mean) SD = 1.6470 (n = 20) fg/kg						lipid = 1.3% (mean) SD = 0.34

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Macoma nasuta, Bent-nose clam	52.6 ng/g dw (grain size < 1 mm) 43.2 ng/g dw (grain size < 0.25 mm) 48.8 ng/g dw (grain size < 0.125 mm)		1,046 ng/g dw (n = 30) 575 ng/g dw (n = 30) 297 ng/g dw (n = 30)			22.2 (dw) 14.5 (dw) 7.3 (dw)	1.63 2.87 3.85	[41]	L; steady state BAFs were calculated with average tissue residues and sediment concentrations from exposure days 42-119
Macoma nasuta, Bent-nose clam	ng/g dw: 1.51 ±0.032 1.26 8.6±0.37 20±3.7 70±7.6		ng/g dw: 6.6±0.83 1.8±0.67 8.2±0.75 11.9±0.84 20.3±2.83				 0.68 0.22 0.64 0.56 0.39	[42]	L; value given is mean ± SE; sediment TOC ranged from 0.84% to 7.4%
Mysis relicta, Mysid	89.97 µg/kg dw (TOC = 22.8%)		Screened mysids: 1.46 µg/kg (whole body) Unscreened mysids: 9.85 µg/kg (whole body)					[40]	L; mysids exposed to field contaminated sediments from Lake Champlain, NY; 24 day exposure; screened mysids were screened from direct contact with sediments (% lipid = 5.94±0.27); unscreened mysids were allowed to burrow into sediment.(% lipid = 5.80±0.18)

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mysis relicta, Mysid	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	8.5 ± 3.5 ng/g (n = 2)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%
Gammarus fasciatus, Amphipod	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	1.611 (mean) SD = 0.7505 (n = 4) fg/kg						lipid = 2.1% (mean) SD = 1.04
Pontoporeia affinis, Amphipod	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	12 ± 8 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%
Orconectes propinquus, Crayfish	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	0.606 (mean) 0.1101 (n = 5) fg/kg						lipid = 1.7% (mean) SD = 0.11
Hydropsyche alterans, Caddisfly larva	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	1.109 (n = 1) fg/kg						lipid = 1.7% (mean)
Fishes									
Alosa pseudoharengus, Alewife	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	27 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 7%

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cottus cognatus, Sculpin	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	39 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 8%
Osmerus mordax, Small rainbow smelt	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	15 ± 2.0 ng/g (n = 4)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%
Osmerus mordax, Large rainbow smelt	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	38 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%
Salmonids: *Oncorhynchus kisutch,* Coho salmon; *Oncorhynchus mykiss (Salmo gairdner),* Rainbow trout; *Salvelinus namaycush,* Lake trout; *Salmo trutta,* Brown trout	10 ± 8.4 ng/g dw (0-3 cm) (n = 38)	14 ±5.1 pg/L surface water (n = 7)	110 ± 82 ng/g (n = 60)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 11%; wild fish.
							4.49	[46]	
Wildlife									
Falco peregrinus, Peregrine falcon			72 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[44]	F; Kola Peninsula, Russia
White leghorn chicken embryo			2,200 µg/kg (egg)	LD50				[43]	L; PCBs were injected into the air cell of eggs

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 510 pg/g[4]		2,900 pg/g[4] (liver)	NOAEL		Log BMF = 0.58		[45]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	12,000 pg/g[4]		54,000 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 0.68			
	23,000 pg/g[4]		105,000 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 0.66			
	41,000 pg/g[4]		181,000 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 0.83			

[1] Concentration units given in wet weight unless otherwise indicated.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 31508-00-6
2,3′,4,4′,5-PENTACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2,3]

Log K_{ow}: —

Log K_{oc}: 5.51 - 6.39 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: In a laboratory study with mink, the lipid-normalized ratios of PCB 118 in liver to food ranged from 3.4 to 5.9 (log BMF = 0.53 to 0.77) [49]. The ratio of PCB 118 in three species of duck to sediment in the lower Detroit River ranged from 21 to 35 [40].

Food Chain Multipliers: For PCBs as a class, the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The biomagnification factor for PCB 118 from alewife to herring gulls in Lake Ontario was 80 [11]. A study of arctic marine food chains measured log biomagnification factors for pentachlorobiphenyls that ranged from 0.71 to 1.05 for fish to seal, 0.28 to 0.49 for seal to bear, and 1.14 for fish to bear [12].

Aquatic Organisms

Partitioning Factors: Steady-state BSAFs for the bent-nose clam ranged from 0.59 to 4.7 in two laboratory studies. The ratio of PCB 118 in carp tissue to sediment from the lower Detroit River was 25.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 118 or other pentachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22]. Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-

tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4',5,5'-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**BCF**	**BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Plankton	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	0.750 (mean) SD = 0.4919 (n = 5) fg/kg					[42]	F; collected in western Lake Erie (offshore Middle Sister Island); sediment TOC = 7.4%; SD = 1.78 lipid = 1.2% (mean) SD = 0.24
Tubifex sp., Oligochaetes	0.017 mg/kg		0.0069 mg/kg					[40]	F; lower Detroit River
Macoma nasuta, Bent-nose clam	ng/g dw: 2.93 ± 0.067 2.5 16.5 ± 1.42 45 ± 9.2 162 ± 16.5		ng/g dw: 20 ± 3.0 12.0 ± 1.89 28.9 ± 2.60 40.3 ± 2.64 66 ± 8.9				 1.08 0.73 1.17 0.82 0.54	[43]	L; value given is mean ± SE; sediment TOC ranged from 0.84% to 7.4%
Macoma nasuta, Bent-nose clam	44.2 ng/g dw (grain size < 1 mm) 36.2 ng/g (grain size < 0.25 mm) 41.6 ng/g dw (grain size < 0.125 mm)		1,049 ng/g dw (n = 30) 550 ng/g dw (n = 30) 296 ng/g dw (n = 30)			30.3 (dw) 18.5 (dw) 8.4 (dw)	2.02 3.28 4.74	[41]	L; steady state BAFs were calculated with average tissue residues and sediment concentrations from exposure days 42-119.

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	BCF	BAF	BSAF	Reference	Comments[3]
Dreissena polymorpha, Zebra mussel	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	2.156 (mean) SD = 0.8847 (n = 20) µg/kg						Lipid = 1.3% (mean) SD = 0.34
Mytilus edulis, Blue mussel		Water column: ~16.0 ng/L ~4.0 ng/L ~0.8 ng/L	Whole body: ~1,780 ng/g dw ~1,000 ng/g dw ~130 ng/g dw					[45]	F; New Bedford Harbor, MA; deployment study; ~ -read all values off figures
Daphnia magna, Freshwater cladoceran		0.1 fg/L	~3.5 ng/mg dw (n = 3)	No significant effect on survival, reproduction, or biomass				[39]	L; 21-day static renewal tests; tissue concentrations are approximations (~), as data were taken from figures
		1.0 fg/L	~130 ng/mg dw (n = 3)	No significant effect on survival, reproduction, or biomass					
Gammarus fasciatus, Amphipod	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	3.113 (mean) SD = 1.7881 (n = 4) µg/kg						Lipid = 2.1% (mean) SD = 1.04

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	BCF	BAF	BSAF	Reference	Comments[3]
Orconectes propinquus, Crayfish	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	2.242 (mean) SD = 0.3628 (n = 5) µg/kg						Lipid = 1.7% (mean) SD = 0.11
Hydropsyche alterans, Caddisfly larva	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	4.780 (n = 1) µg/kg						Lipid = 1.7% (mean)
Mysis relicta, Mysid	135.73 µg/kg dw (TOC = 22.8%)		Screened mysids: 2.39 µg/kg (whole body) Unscreened mysids: 15.67 µg/kg (whole body)					[44]	L; mysids exposed to field contaminated sediments from Lake Champlain, NY; 24-day exposure screened mysids were screened from direct contact with sedi-ments (% lipid = 5.94 ± 0.27); unscreened mysids were allowed to burrow into sediment.(% lipid = 5.80 ± 0.18)

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Salvelinus namaycush namaycush, Lake trout	0.87 ng/g ± 0.11 n = 4	0.20 ng/L ± 0.29 n = 11	290 ng/g lipid					[46, 47]	F; Siskiwit Lake, Isle Royale, Lake Superior; tissue concentrations are means of concentrations measured in several size classes; organic carbon content of sediment was not presented.
Coregonus culpeaformis neohantoniensus, Whitefish	0.87 ng/g ± 0.11 n = 4	0.20 ng/L ± 0.29 n = 11	280 ng/g lipid						
Salmonids						8.15	4.09	[13]	F; %lipid = 11; %sed OC = 2.7
							1.72	[50]	F
Cyprinus carpio, Carp	0.017 mg/kg (n = 1)		0.42 ± 0.26 mg/kg (n = 9)					[40]	F; lower Detroit River
Wildlife									
Bucephala clangula, Goldeneye	0.017 mg/kg (n = 1)		0.36 ± 0.041 mg/kg (n = 3)					[40]	F; lower Detroit River

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Aythya affinis, Lesser scaup	0.017 mg/kg (n = 1)		0.52 ± 0.26 mg/kg (n = 7)					[40]	F; lower Detroit River
Aythya marila, Greater scaup	0.017 mg/kg (n = 1)		0.59 ± 0.10 mg/kg (n = 3)					[40]	F; lower Detroit River
Falco peregrinus, Peregrine falcon			450 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[48]	F; Kola Peninsula, Russia
Mustela vison, Mink	Diet: 1,660 pg/g[4]		8,500 pg/g[4] (liver)	NOAEL		log BMF = 0.53		[49]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	35,000 pg/g[4]		20,000 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		log BMF = 0.56			
	68,000 pg/g[4]		284,000 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		log BMF = 0.63			
	125,000 pg/g[4]		478,000 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		log BMF = 0.77			

[1] Concentration units expressed in wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, SAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 57465-28-8
3,3′,4,4′,5-PENTACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1]
0.004 - 0.099 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: 6.2 - 6.85 [2], No data [4]

Log K_{oc}: 6.09 - 6.73 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: No data [5]

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: Partitioning factors for PCB 126 in wildlife were not found.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factor for pentachlorobiphenyls from alewife to herring gulls in Lake Ontario ranged from 1.18 to 2.00 [11]. A study of arctic marine food chains measured biomagnification factors for pentachlorobiphenyls that ranged from 0.71 to 1.05 for fish to seal, 0.28 to 0.49 for seal to bear, and 1.14 for fish to bear [12]. No specific food chain multipliers were identified for PCB 126.

Aquatic Organisms

Partitioning Factors: In an 83-day laboratory study with three-spined stickleback, the lipid-normalized ratio of PCB 126 in food to fish tissue ranged from 3.8 to 6.1. A log bioconcentration factor (BCF) for deployed mussels in New Bedford Harbor, MA, was approximately 6.90, as reported in the attached table.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 126 or other pentachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 126

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BAF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Mytilus edulis, Blue mussel		1993: particulate 0.2 µg/L ±0.1 n = 9 dissolved 0.02 µg/L ±0.01 n = 9 1994: particulate 0.2 µg/L ±0.1 n = 3 dissolved 0.03 µg/L ±0.01 n = 3	~20 ng/g dw (whole body)		6.90			[39]	F; New Bedford Harbor, MA; deployment study; tissue concentrations were only presented for 1994 samples; BCF and tissue concentrations read from figures (~)
Fishes									
Gasterosteus aculeatus, Three-spined stickleback						0.78 (male) 0.58 (female)		[41]	L; 83-day dosing study; BAF = lipid-normalized concentration in fish divided by the lipid-normalized concentration in food
Myoxocephalus quadricornis, Four-horn sculpin	0.013 ng/g dw		0.035 ng/g (liver) 0.068 ng/g (whole body)					[40]	F; collected in or near Hamlet in Cambridge Bay, NW Territories, Canada
Salmonids							3.21	[45]	F

Summary of Biological Effects Tissue Concentrations for PCB 126

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BAF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Wildlife									
Sterna hirundo, Common tern (embryo)			45 µg/kg[4] (egg)	35% embryo mortality (through hatching)				[42]	L; PCBs were injected into the air cell of eggs
Falco peregrinus, Peregrine falcon			1.3 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[44]	F; Kola Peninsula, Russia
Falco sparverius, American kestrel (embryo)			65 µg/kg[4] (egg)	LD50 (through hatching)				[42]	L; PCBs were injected into the air cell of eggs
Falco sparverius, American kestrel (nestling)			156 µg/kg[4] (liver)	Histopathology of liver, thyroid, and spleen				[42]	L
Colinus virginianus, Bobwhite (embryo)			24 µg/kg[4] (egg)	LD50 (through hatching)				[42]	L; PCBs were injected into the air cell of eggs
White leghorn chicken (embryo)			0.4 µg/kg (egg)	LD50				[42]	L; PCBs were injected into the air cell of eggs from day 4 of incubation through hatching
White leghorn chicken (embryo)			3.1 µg/kg (egg)	LD50				[43]	L; PCBs were injected into the air cell of eggs from day 7 through day 10 of incubation

[1] Concentration units expressed in wet weight unless otherwise indicated.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[2] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 38380-08-4
2,3,3′,4,4′,5-HEXACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1], 0.004 - 0.038 mg/L [2] **Half-Life:** No data [2,3]

Log K_{ow}: 6.7 - 7.3 [2] **Log K_{oc}:** 6.59 - 7.18 L/kg organic carbon

Human Health

Oral RfD: No data [5] **Confidence:** —

Critical Effect: —

Oral Slope Factor: No data [5] **Carcinogenic Classification:** No data [5]

Wildlife

Partitioning Factors: In a laboratory study with mink, the lipid-normalized ratios of PCB 156 in liver to food ranged from 5.5 to 11.6. The ratio of PCB 156 in tissues of three species of duck to sediment in the lower Detroit River ranged from 27 to 41.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factors for hexachlorobiphenyls from alewife to herring gulls in Lake Ontario ranged from 1.30 to 2.14 [11]. A study of arctic marine food chains measured log biomagnification factors for hexachlorobiphenyls that ranged from 0.99 to 1.36 for fish to seal, 0.97 to 1.26 for seal to bear, and 2.23 for fish to bear [12]. No specific food chain multipliers were identified for PCB 156.

Aquatic Organisms

Partitioning Factors: In Lake Ontario, ratios of PCB-156 in tissue (wet weight) to sediment (dry weight) for plankton, oligochaetes, mysids, and amphipods were 0.10, 0.14, 0.57, and 1.9 respectively; ratios in sculpin, alewife, rainbow smelt, and salmonids were 6.7, 3.0, 2.9, and 16, respectively. In carp from the lower Detroit River the tissue to sediment ratio (wet weight) was 25. BSAFs for clam in a laboratory study ranged from 0.16 to 0.67.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 156 or other hexachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 156

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Plankton (a mixture of primarily phytoplankton and some zooplankton)	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	0.2 ± 0.1 ng/g (n = 3)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 0.5%
Mainly *Tubifex tubifex* and *Limnodrilus hoffmeisteri,* Oligochaete	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	0.3 ± 0.4 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 1%
Tubifex sp, Oligochaetes	0.0024 mg/kg (n = 1)		0.0016 mg/kg (n = 1)					[39]	F; lower Detroit River
Macoma nasuta, Bent-nose clam	ng/g dw: 0.60 ± 0.019 0.48 NA 11.6 ± 2.29 34 ± 5.3		ng/g dw: 2.6 ± 0.59 1.93 ± 0.284 2.61 ± 0.192 2.89 ± 0.215 4.1 ± 0.77				 0.67 0.61 0.51 0.23 0.16	[40]	L; values given are mean ± SE; sediment TOC ranged from 0.84% to 7.4%. *Macoma* were exposed to 5 sediments containing different PCB concentra-tions; NA means number was not legible.
Pontoporeia affinis, Amphipods	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	3.9 ± 2.3 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%

Summary of Biological Effects Tissue Concentrations for PCB 156

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mysis relicta, Mysids	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	1.2 ± 0.1 ng/g (n = 2)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%
Fishes									
Salmonids: *Oncorhynchus velinus namaycush,* Coho salmon; *Oncorhynchus mykiss* (*Salmo gairdneri*), Rainbow trout; *Salvelinus namaycush,* Lake trout; *Salmo trutta,* Brown trout	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	34 ± 27 ng/g (n = 60)				3.97	[13]	F; Lake Ontario; value is mean ± SD; lipid content = 11%
Cyprinus carpio, Carp	0.0024 mg/kg (n = 1)		0.061±0.024 mg/kg (n = 9)					[39]	F; lower Detroit River
Cottus cognatus, Sculpin	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	14 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 8%
Alewife	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	6.3 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 7%
Osmerus mordax, Small rainbow smelt	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	2.7 ± 1.9 ng/g (n = 4)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%

Summary of Biological Effects Tissue Concentrations for PCB 156

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	BCF	BAF	BSAF	Reference	Comments[3]
Osmerus mordax, Large rainbow smelt	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	6.1 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%
Wildlife									
Bucephala clangula, Goldeneye	0.0024 mg/kg (n = 1)		0.064±0.018 mg/kg (n = 3)					[39]	F; lower Detroit River
Aythya affinis, Lesser scaup	0.0024 mg/kg (n = 1)		0.090±0.044 mg/kg (n = 7)					[39]	F; lower Detroit River
Aythya marila, Greater scaup	0.0024 mg/kg (n = 1)		0.098±0.0091 mg/kg (n = 3)					[39]	F; lower Detroit River
Falco peregrinus, Peregrine falcon			82 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[41]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for PCB 156

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 110 pg/g[4]		920 pg/g[4] (liver)	NOAEL		Log BMF = 0.74		[42]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	1,300 pg/g[4]		12,000 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 0.96			
	2,800 pg/g[4]		23,000 pg/g[4] (liver)	reduced kit body weights followed by reduced survival		Log BMF = 0.91			
	5,000 pg/g[4]		37,100 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 1.06			

[1] Concentration units expressed in wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 32774-16-6
3,3′,4,4′,5,5′-HEXACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1], 0.5 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: 7.4 [5]

Log K_{oc}: 7.27 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: In a laboratory study with mink, the lipid-normalized ratios of PCB 169 in liver to food ranged from 12.4 to 21.4.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factors for hexachlorobiphenyls from alewife to herring gulls in Lake Ontario ranged from 1.30 to 2.14 [11]. A study of arctic marine food chains measured log biomagnification factors for hexachlorobiphenyls that ranged from 0.99 to 1.36 for fish to seal, 0.99 to 1.26 for seal to bear, and 2.23 for fish to bear [12]. Log BMFs ranged from 1.09 to 1.33 for mink fed PCB 169 in the diet [40].

Aquatic Organisms

Partitioning Factors: In an 83-day laboratory study with three-spined stickleback, the lipid-normalized ratio of PCB 169 in food to fish tissue (log BAF) ranged from 0.50 to 0.79.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 169 or other hexachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [18], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [19]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 169

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	BCF	BAF	BSAF	Reference	Comments[3]
Fishes									
Gasterosteus aculeatus, Three-spined stickleback						0.79 (male) 0.50 (female)		[39]	L; 83-day dosing study; BAF = lipid-normalized concentration in fish divided by the lipid-normalized concentration in food
Wildlife									
Mustela vison, Mink	Diet: 2 pg/g[4]		65 pg/g[4] (liver)	NOAEL		Log BMF = 1.33		[40]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	5 pg/g[4]		65 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 1.10			
	10 pg/g[4]		120 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 1.09			
	20 pg/g[4]		205 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 1.20			

[1] Concentration units expressed as wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: SUBSTITUTED PHENOLS

Chemical Name (Common Synonyms): PENTACHLOROPHENOL (PCP) **CASRN:** 87-86-5

Chemical Characteristics

Solubility in Water: 14 mg/L at 20°C [1]

Half-Life: 23 - 178 days, sediment grab sample, estimated unacclimated aqueous aerobic biodegradation [2]

Log K_{ow}: 5.09 [3]

Log K_{oc}: 5.00 L/kg organic carbon

Human Health

Oral RfD: 3×10^{-2} mg/kg/day [4]

Confidence: Medium, uncertainty factor = 100

Critical Effect: Liver and kidney pathology

Oral Slope Factor: 1.2×10^{-1} per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for pentachlorophenol in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for pentachlorophenol in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for pentachlorophenol in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for pentachlorophenol in aquatic organims were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Technical PCP has been reported to contain chlorodiphenylethers, chlorodibenzo-*p*-dioxins, chlorodibezofurans, and hydroxychlorodiphenylethers, whereas commercial PCP contains significant quantities of tetrachlorophenol [5]. These impurities contribute to PCP toxicity, especially sublethal effects at low concentrations of PCP. PCP undergoes rapid degradation (by chemical, microbiological, or photochemical processes) in the environment.

PCP affects energy metabolism by increasing oxygen consumption and altering the activities of several glycolytic and citric acid cycle enzymes and by increasing the consumption rate of stored lipid [6]. PCP toxicity ranged from 3 to 100 µg/L for invertebrates and 1 to 68 µg/L for fish. In oral doses PCP was fatal to birds at 380 to 580 mg/kg. Adverse sublethal effects in birds were observed in a diet containing 1 mg/kg of PCP [5].

Residues above 11 mg/kg in bird tissues were associated with acute toxicity. Studies with birds showed that PCP killed various species at single oral doses of 380 to 504 mg/kg at dietary concentration of 3,850 mg/kg, fed over a 5-day period. Residues of PCP in dead birds were 11 mg/kg in brain, 20 mg/kg in kidney, and 46 mg/kg in liver [7]. Chickens fed 1 mg/kg PCP over an 8-week period accumulated substantial amounts of PCP: 2 mg/kg in muscle, 80 mg/kg in kidney, 25 mg/kg in liver [8]. Residues of PCP in dead organisms after treatment in rice fields were 8.1 mg/kg in frogs and 36.8 mg/kg in snails, and the residues ranged from 31.2 to 59.5 mg/kg in three fish species [7].

Accumulation of PCP is pH-dependent; at pH 4, PCP is completely protonated and therefore highly lipophilic. At this pH, PCP has the greatest accumulation potential. Conversely, PCP is completely ionized at pH 9. Early studies estimated the lethal body burden or critical body residue for goldfish was 0.36 mmol PCP/kg [12] and 0.75 mmol PCP/kg for brown trout [13] (these were prior to 1985 and are not included in the following table). Experiments with rainbow trout [9] showed that neither the twofold difference in body weight nor the 3-percent difference in body lipid content gave fish resistance to the toxicity of PCP. Mean lethal body residues (= critical body residue) ranged from 0.08 to 0.15 mmol/kg. The PCP accumulation by medaka (*Oryzias latipes*) acclimated in freshwater and saltwater decreased with increased salinity [10]. However, the amount of PCP accumulated by killifish acclimated to freshwater was greater than that accumulated by killifish acclimated to saltwater. The growth rate of bluegill was reduced by 75 percent during the 22-day subchronic exposure to 173 µg/L of PCP [11]. The critical body residue for chlorophenols for fathead minnows ranged from 1.1 to 1.7 mmol/kg [14].

PCP is rapidly accumulated and rapidly excreted, and it has no tendency to persist in living organisms. However, PCP tends to accumulate in mammalian tissues unless it is efficiently conjugated into a readily excretable form [15]. Humans eliminate 75 percent of all PCP in the urine. Rats (*Rattus* sp.) and mice can eliminate PCP in the urine very efficiently; however, rhesus monkeys (*Macaca mulatta*) are unable to excrete PCP efficiently.

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Glycera dibranchiata, Polychaete			6.64 mg/kg (whole body)[4]	Cellular, LOED				[20]	L; reduced ability of amebocytes to recognize foreign material
			1.55 mg/kg (whole body)[4]	Physiological, LOED				[20]	L; reduced antibacterial activity
Neanthes virens, Polychaete - sandworm			28 mg/kg (whole body)[4]	Physiological, LOED				[23]	L; significant reduction in coelomic fluid glucose level, number of replicates is 8 to 10
			112 mg/kg (whole body)[4]	Physiological, LOED				[23]	L; decrease in tissue glycogen
			13.8 mg/kg (whole body)[4]	Mortality, ED100				[32]	L; lethal body burden
			469 mg/kg (extractable lipid)[4]	Mortality, ED50				[9]	L; median survival time with fish fed low fat diet for 11 weeks then PCP exposure
			471 mg/kg (extractable lipid)[4]	Mortality, ED50				[9]	L; median survival time with fish fed high fat diet for 11 weeks then PCP exposure

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			29.8 mg/kg (whole body)[4]	Mortality, ED50				[9]	L; median survival time with fish fed low fat diet for 11 weeks then PCP exposure
			39.4 mg/kg (whole body)[4]	Mortality, ED50				[9]	L; median survival time with fish fed high fat diet for 11 weeks then PCP exposure

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Eisenia fetida, Earthworm,	6.75 mmol/kg 3.75 mmol/kg 2.10 mmol/kg 1.20 mmol/kg 0.68 mmol/kg 0.38 mmol/kg 0.21 mmol/kg 0.12 mmol/kg 0.068 mmol/kg 0.038 mmol/kg		1.39-2.65 mmol/kg 0.74-1.19 mmol/kg 0.62-1.35 mmol/kg 0.56-1.16 mmol/kg 0.59-1.58 mmol/kg 0.51-0.80 mmol/kg 0.33-0.84 mmol/kg 0.79-1.16 mmol/kg 0.44-1.29 mmol/kg 0.21 mmol/kg					[19]	L
Physa sp., Snail			0.33 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 24 hours

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Anodonta anatina, Duck mussel			3.1 mg/kg (whole body)[4]	Behavior, LOED				[30]	L; behavioral changes, distended foot could not be retracted
			1.5 mg/kg (whole body)[4]	Behavior, NOED				[30]	L; no effect on behavior
			3.1 mg/kg (whole body)[4]	Mortality, NOED				[30]	L; no effect on mortality
Mytilus edulis, Blue mussel	5 µg/kg		32-244 µg/kg					[16]	F
Mytilus edulis, Mussel			2.34 mg/kg (whole body)[4]	Physiological, LOED				[34]	L; significant increase in anoxic heat dissipation (j/h/g)at test concentration
			2.34 mg/kg (whole body)[4]	Physiological, NA				[34]	L; 10% reduction in anoxia tolerance as percent of controls
			9.9 mg/kg (whole body)[4]	Physiological, NA				[34]	L; 36% reduction in anoxia tolerance as percent of controls
			29.4 mg/kg (whole body)[4]	Physiological, NA				[34]	L; 54% reduction in anoxia tolerance as percent of controls

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mercenaria mercenaria, Quahog clam			0.498 mg/kg (whole body)[4]	Physiological, LOED				[21]	L; impaired ability to clear flavobacterium
			0.498 mg/kg (whole body)[4]	Mortality, NOED				[21]	L; no effect on mortality
Daphnia magna, Cladoceran			0.45 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 24 hours
Pontoporeia hoyi, Amphipod			48.6 mg/kg (whole body)[4]	Survival, ED50				[27]	L
		200 mmol/L	3.8 mmol/kg	lethal				[17]	L
		300 mmol/L	5.6 mmol/kg	lethal					
		430 mmol/L	7.6 mmol/kg	lethal					
			CBR = 0.33 to1.1 mmol/kg						
Chironomus riparius, Midge			1.1 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; no effect on swimming behavior
			0.87 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; no effect on swimming behavior
			0.38 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; no effect on swimming behavior

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Strongylocentrotus purpuratus, Purple sea urchin			95 mg/kg (whole body)[4]	Development, LOED				[22]	L; increase in number of abnormal embryos
			927 mg/kg (whole body)[4]	Development, LOED				[22]	L; genotoxicity, anaphase aberrations
			662 mg/kg (whole body)[4]	Reproduction, LOED				[22]	L; reduced fertilization of embryos
Fishes									
Oncorhynchus kisutch, Coho salmon		1.3 µg/L	21 µg/kg					[17]	L
Oncorhynchus mykiss, Rainbow trout		1.3 µg/L	24 µg/kg						

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
		1100 mmol/L	3.8 mmol/kg	lethal				[17]	L
		1150 mmol/L	4.0 mmol/kg	lethal					
		1300 mmol/L	4.3 mmol/kg	lethal					
		1400 mmol/L	4.4 mmol/kg	lethal					
		1600 mmol/L	5.2 mmol/kg	lethal					
		1700 mmol/L	6.0 mmol/kg	lethal					
		2300 mmol/L	8.0 mmol/kg	lethal					
			CBR = 0.08 to 0.15 mmol/kg						
Salmo trutta, Brown trout		0.2 mg/l	200 mg/kg (whole body)[4]	Mortality, ED50				[13]	L; lethal body burden
Salvelinus namaycush, Lake trout		1.3 µg/L	11 µg/kg					[17]	L
Carassius auratus, Goldfish			82 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			97 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			89 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			88 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			97 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			99 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			87 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			86 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			82 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			107 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			92 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			89 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			100 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			82 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			99 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			86 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			95 mg/kg (whole body)[4]	Mortality, ED50				[26]	L; mortality
Pimephales promelas, Fathead minnow			CBR = 1.1-1.7 mmol/kg	50% mortality				[14]	L
Pimephales promelas, Fathead minnow			69 mg/kg (whole body)[4]	Growth, LOED				[33]	L; pH was 8.5
			22.1 mg/kg (whole body)[4]	Growth, LOED				[33]	L; pH was 8.0
			25.1 mg/kg (whole body)[4]	Growth, LOED				[33]	L; pH was 7.5
			43.8 mg/kg (whole body)[4]	Morphology, LOED				[33]	L; pH was 8.0
			69 mg/kg (whole body)[4]	Morphology, LOED				[33]	L; pH was 8.5

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			35.1 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 8.5
			45.9 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 6.5
			45.9 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 6.5
			43.8 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 8.0
			12.6 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 8.0
			12.3 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 7.5
			45.9 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 6.5
			35.1 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 8.5
			35.1 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 8.5
			22.1 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 8.0
			21.5 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 6.5

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			25.1 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 7.5
			17.8 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 8.5
			22.1 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 8.0
			25.1 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 7.5
			21.5 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 6.5
			25.1 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 7.5
			45.9 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 6.5
			69 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 8.5
			43.8 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 8.0
Ictalurus nebulosus, Brown bullhead		5.7 µg/L	260 µg/kg					[18]	F

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oryzias latipes, Medaka		100 µg/L	41.02 µg/g 38.02 µg/g 37.50 µg/g					[10]	L
Gambusia affinis, Mosquito fish			0.8 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 24 hours
Osmerus mordax, Rainbow smelt		1.3 µg/L	6 µg/kg					[17]	L
Leuciscus idus, Golden ide			13 mg/kg (whole body)[4]	Mortality, NOED				[24]	L; no effect on survivorship in 3 days
Micropterus salmoides, Largemouth bass			9.6 mg/kg (whole body)[4]	Behavior, LOED				[31]	L; reduced success rate of prey capture
			9.6 mg/kg (whole body)[4]	Growth, LOED				[31]	L; reduction in growth
			9.6 mg/kg (whole body)[4]	Physiological, LOED				[31]	L; reduced food conversion efficiency, condition factor
			10.8 mg/kg (whole body)[4]	Mortality, NOED				[31]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Perca flavescens, Yellow perch		5.7 µg/L	260 µg/kg					[18]	F

[1] Concentration units based on wet weight unless otherwise noted.

[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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